



Assessment of Seasonal Variations of Heavy Metals and Microbial Parameters on Well Water Quality in Urban Centre, Effluent Locations and Non-Effluent Location of Kano Metropolis, Nigeria

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ABSTRACT: The groundwater consists of about 20% of the earth's fresh water is the most widely used for drinking. Hence, the objective of this paper was to assess the seasonal variations of heavy metals and microbial parameters on well water quality in Urban Centre (UC), Effluent Locations (EL) and Non-Effluent Location (NEL) of Kano metropolis, Nigeria using appropriate standard techniques. The research collected 768 water samples from 48 wells at three different locations: Urban Centre (UC), Effluent Locations (EL) and Non-Effluent Location (NEL) in the city during dry and wet seasons in one year and subjected samples to laboratory analysis for determination of the concentrations of elements and bacteria in line with American Public Health Association (APHA, 2005). Higher mean values of Cadmium, Chromium, Mercury, Arsenic, Iron, Lead, Zinc, Manganese, Total Coliform and Escherichia Coli of 0.14mg/L, 5.11mg/L, 0.095mg/L, 0.15mg/L, 0.53mg/L, 3.1mg/L, 8.62mg/L and 4.1mg/L respectively at EL except Cadmium (UC). Analysis of Variance (ANOVA) and T-test 0.05% confidential level showed that Chromium $F(2, 3) = 17.225$, $p = 0.019$, Arsenic $F(2, 3) = 16.11$, $p = 0.031$ and Iron $F(2, 3) = 17.135$, $p = 0.021$ while microbial parameters showed that E. coli $F(2,3) = 11.88$ $p = 0.038$ parameters wells located at the UC, EL NEL areas of Kano. The results showed that heavy metal concentrations and microbial contamination in the metropolis are significantly different from each other where the mean level is significant at $P < .05$ across different locations, with higher levels found in industrial and urban areas during the rainy season. These findings highlight the need for improved management and monitoring of well water quality in Kano metropolis to protect public health.

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One very important resource that occupies about 70% of the earth is water. Every life and the existence of ecosystem depend on water. Hence, the statement that water is life is absolutely germane. This fundamental resource exist on the surface of the earth in a form of oceans, seas, lakes, rivers, ponds, creeks, reservoirs and streams as well as underneath the surface known

as groundwater in a form of well water and aquifers which provide water for drinking. United Nations Water (UN Waters 2019; Mshelia and Mbaya, 2024) reported that an estimated 2.2 billion in the world do not have access to portable drinkable water while 785 million people out of the 2.2 billion do not get fundamental water service. Additionally, about 44%

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of the Sub-African population lacks clean drinkable and reliable water supplies (WHO, 2015; United Nations, 2019; Corcoran *et al.*, 2010). The issue is not different in Nigeria; the Africa's populous nation of over 227.71 million people based on O'Neil (2024) population projection which reported about 64% also do not have access to good and drinkable water (UNESCO, 2016). The inability of the people to have access to clean water and other related services emanate from the pollution of the drinking water from point and non-point sources. In most cases, human activities trigger water pollution through the addition of impurities, faeces and other wastes from homes, industries, institutions, commercial centres and farms beyond the water carrying capacities of the substances culminating into scarcity of portable drinking water (Mshelia *et al.*, 2020a; Global Water Security, 2012; Mshelia and Mbaya 2024; Kankara, 2019). Friedl (2013a) posited that the groundwater is the most widely used kind of water for drinking and it comprises of about 20% of the earth's fresh water which is mostly recharged by rainfall. Melting snow and leaks from lakes are the other sources of groundwater. When rain falls, great volume seeps into the ground and occupies the pores, fractures and other available spaces under the ground, passing through the unsaturated zones (the section underneath the ground surface contains water and air) and fills the aquifer layers also refer to as the saturated zones; the area that fully brimmed with groundwater. Groundwater is naturally, clean and good for consumption and other domestic uses for basically soil acts as a filter or sieve and makes the groundwater most often free of micro-organisms such as bacteria that may cause diseases (Friedl 2013a; Mshelia 2024a). Nevertheless, Mshelia (2023; 2024b) is of the view that human activities and geological processes can lead to contaminations of the groundwater. This can occur when toxic chemicals from industries, agricultural practices, households, communities and institutions are released into the environment and eventually seep or infiltrate into the groundwater. Similarly, wells located in swampy areas, dumpsites, wastewater canals, soakaways, filthy and wells without casings or caps are likely to get contaminated (Mshelia 2023; Audrey, 2019).

Mshelia and Mbaya (2024) reported that three in every ten households in Kano Metropolis depend on well water for drinking and other domestic uses, however, it is very sad to note that most of the wells are located in filthy surrounding, close to toilet and near wastewater canals, thereby aiding in the recharge of the wells and gives room for possible contamination with common elements and microbial parameters. Contaminated well water may lead to health issue such as stomach disorders otherwise known as

gastroenteritis, bloody diarrhea, hemolytic uremic syndrome, dysentery and cholera among others if consumed. Under severe situation, it could results to cancer, anemia and high blood pressure (Freidl 2013b; Mshelia, 2023). Therefore, good hygiene, sanitation and environmental management in every location of settlement are paramount. It is against these backdrops that the study investigated the spatial-temporal variations of heavy metals and microbial parameters on well water in three different locations of the metropolis attributable to human activities and geological processes with the view to proffering sustainable water management to meeting the 2015 Sustainable Development Goals (SDGs) 6: Clean Water and Sanitation (Mshelia *et al.*, 2021; Mshelia *et al.*, 2020). Hence, the objective of this paper was to assess the seasonal variations of heavy metals and microbial parameters on well water quality in Urban Centre (UC), Effluent Locations (EL) and Non-Effluent Location (NEL) of Kano metropolis, Nigeria.

MATERIALS AND METHODS

Study Area: Kano Metropolis is located between latitudes $11^{\circ} 55' 23.93''\text{N}$ to $12^{\circ} 3' 53.10''\text{N}$ of the Equator and longitude $8^{\circ} 27' 42.26''\text{E}$ to $8^{\circ} 3' 41.62''\text{E}$ of the Greenwich Meridian and encompasses total landmass of 499km^2 (see Figure 1). The city centre which is the urban area and the outskirt covering most parts of Kwombutso LGAs where Effluent and Non-effluent areas are located (Mshelia, 2023). Well water samples were collected from these locations for laboratory analysis. The climate of Kano is tropical in nature according to Koppen's classification. The average annual temperature and rainfall is about 28°C and 700mm (NiMET, 2021).

Sample Collections: APHA (2005) methods were adapted for the collection of wells water samples at the three locations purposefully selected. These are: Urban Centre (UC), Effluent Locations (EL) and Non-Effluent Location (NEL) and water samples were collected from wells during dry and wet seasons as shown in Table 1. Eight (8) wells were systematically selected at each of the three locations where well water samples were collected 16 times at 1 week interval in 4 months during dry and wet seasons over a period of one year. Therefore, a total of 768 water samples at 48 locations were collected in the Metropolis (see Table 2) and subjected to laboratory analysis for the determination of heavy metals and microbial parameters.

Selection of Heavy Metals and Microbial Parameters: Principal component analysis (PCA) using the SPSS statistics procedures was employed in the selection of the heavy metals for the determination of their

concentrations in the three different locations in the metropolis owing to their capability of threatening water quality and eventually leads to health issues. The PCA produced Chromium (Cr), Cadmium (Cd), Mercury (Hg), Lead (Pb), Iron (Fe²⁺), Zinc (Zn) and Manganese (Mn) as well as Total Coliform Count (TCC) and Escherichia Coli (E.coli).

Laboratory Analysis: Heavy metals were determined using Shimadzu Atomic Absorption Spectrophotometer (AAS Model AA-6800), Japan

model, equipped with Zeeman background correction and graphite furnace, Japan model at a temperature of < 4°C. Different solutions of concentration standard were prepared to produce the calibration. Thereafter, the instrument was put on zero by running each reagent blank and metal concentrations determined three times and average values were taken. Microbial parameters determined are Total Coliform Counts (TCC) and Escherichia Coli (E.coli) using the Membrane Filter (MF) technique (APHA, 2005).

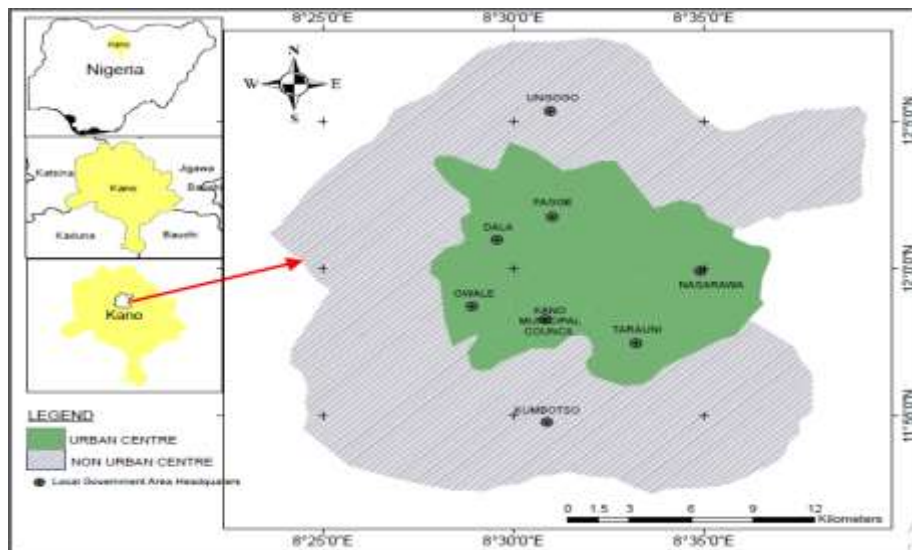


Fig 4.4: Kano Metropolis

Source; GIS Unit, Geography Department, Federal University Gashua (2022)

Table 1: Different Geo Location Areas in Kano

Geo Location Sampled Areas	Location/Settlement	Remark
Urban Centre (UC)	Fagge, Birni, Sabon-Gari, Daurayi, Gwale	Most populated and commercial areas (Ancient Kano city)
Effluent Location (EL)	Challawa industrial layout	Located very close to wastewater canals and industrial areas
Non Effluent Location (NEL)	Lamido GRA, Drs Qtrs, State Road, Challawa	Peri Urban Centre, GRAs Challawa village, & estates

Source: Field Survey, (2022)

Table 2: Summary of Well Water Collected in the Metropolis

Location	Season	Type of sample	Period collected	No of sampled points	Frequency of samples collected at each sampled point
Effluent Location (EL)	Dry	Well	08/01/ – 19/04/2022	8	16(8) = 128
	Wet	Well	23/06 – 08/09/2022 (@1 week interval)	8	16(8) = 128
Non Effluent Location (NEL)	Dry	Well	09/01/22 – 20/04/2022	8	16(8) = 128
	Wet	Well	24/06 – 09/09/2022 (@1 week interval)	8	16(8) = 128
Urban Centre (UC)	Dry	Well	10/01 – 26/04/2022	8	16(8) = 128
	Wet	Well	28/06 – 10/09/2022 (@1 week interval)	8	16(8) = 128
				48	768 Samples

Source: Field Survey (2022)

Statistical Analysis: The study employed the Analysis of Variance (ANOVA) and T-test for the analysis of the variability between spatial and temporal variations at 0.05% confidential level, Obeta and Ocheje (2013)
Formula for AVOVA:

$$Cm = \frac{(\text{Total of all observation})^2}{\text{Total number of observations}} \quad (1)$$

Where Cm = correction for mean; SS (total) = total sum of squares; = (Sum of squares of all observations) – cm = –cm; SST = sum of squares for treatment; = (sum of square of treatments totals with each square divided by the number of Observations for that treatment) – cm; SS Sum of squares for error = SS (total)-SST; MST= mean square for treatments=SST/K-1; MS = mean square for error = SS1; F= test statistic =MST/ MS; Where n= total number of observations; K = Number of treatments; T₁ = total of treatments I (i=1,2.....k)

T-Test (Formula tutorvista (2020).com/math/anova-formula.html)

$$T = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}} \quad (2)$$

Where S₁ = standard deviation of first sets of the values; S₂ = standards deviation of second sets of the values; n₁ = standard deviation of first sets of the values; n₂ = standard deviation of second sets of the values

RESULTS AND DISCUSSION

Variations of Heavy Metals on Well Water at Urban Centre (UC), Effluent Location (EL) and Non-Effluent Location (NEL) during Wet and Dry Seasons: The results of the analysed heavy metals and microbial parameters on well water (W1 – W8) collected at Urban Centre (UC), Effluent Location (EL) and Non-Effluent Location (NEL) during wet season and determined in the laboratory.

Table 3 and 4 showed Cd and Cr mean ranged concentrations of 0.009 – 0.015mg/L and 0.56 – 3.42mg/L at UC; 0.001 – 0.14mg/L and 1.25 – 4.55mg/L at EL; 0.001 – 0.011mg/L and 0.16 – 4.65mg/L at NEL respectively during wet season while dry season showed the Cd and Cr mean concentrations ranged from 0.005 - 0.015mg/L and from 0.38 - 0.90mg/L at UC; 0.02 - 0.015mg/L and 0.15 to 6.86mg/L at EL and 0.001 - 0.010mg/L and 0.047 - 1.12mg/L at NEL respectively above the WHO (2010) and NSDWQ (2015) threshold limit of

0.003mg/L for Cd and 0.05mg/L for Cr. The Hg recorded mean values of 0.001 – 0.052mg/L, 0.004 – 0.095mg/L, 0.00 – 0.02mg/L during wet season at UC, EL and NEL respectively. The dry season recorded Hg mean ranged concentrations between 0.001 and 0.005mg/L at UC, 0.002 and 0.021mg/L at EL and 0.00 and 0.008mg/L at NEL as also reported by Mshelia and Bulama (2023) in their work on concentration and comparison of groundwater quality in Kano Metropolis.

More still, heavy metals such as As, Pb and Fe recorded mean values between 0.01 and 1.35mg/L, 0.02 and 0.15mg/L, 0.01 and 0.15mg/L of As; 0.15 and 0.32mg/L, 0.02 and 0.53mg/L, 0.003 and 0.53mg/L of Pb and 0.21 and 2.62mg/L, 0.21 and 2.50mg/L, 0.14 and 2.50mg/L of Fe at UC, EL and NEL respectively.

Similarly, during the dry season As, recorded between 0.003 and 0.07mg/L at UC, 0.01 and 0.08mg/L at EL and 0.01 and 0.04mg/L at NEL; Pb between 0.01 and 0.30mg/L at UC, 0.01 and 0.65mg/L at EL and 0.005 and 0.42mg/L at NEL; Fe from 0.03 and 0.4mg/L at UC, 0.35 and 1.25mg/L at EL, 0.10 and 1.12mg/L at NEL.

Similar results were reported by Dey *et al.* (2023) in their work on seasonal variations in water quality parameter on Gudlavalluru engineering pond in urban areas. In the same vein, during the dry season Zinc mean ranged concentrations recorded between 1.12 and 2.54mg/L at UC, 2.65 and 5.54mg/L at EL and 0.55 and 3.37mg/l at NEL while Mn recorded between 0.01 and 0.22mg/L, 0.55 and 5.19mg/L and 0.15 and 1.00mg/L at UC, EL and NEL respectively. Highest values of 5.54mg/L of Zn and 5.19mg/L as against recommended values of 3.0mg/L and 0.5mg/L by WHO and 3.0mg/L and 0.2mg/L by NSDWQ.

Microbial Parameters in Groundwater at Kano Metropolis during Rainy and Dry Seasons: TCC mean concentrations of well water during rainy season ranged from 78 – 176cfu/100ml, 67 - 142cfu/100ml and as 25 - 10cfu/100ml at UC, EL and NEL respectively while the E.coli recorded mean ranged from 33 - 165cfu/100ml, 52 – 156cfu/100ml and 20 - 165 cfu/100ml at the UC, EL and NEL respectively (see Table 3 and 4).

Additionally, mean values within the range of 65 - 141cfu/100ml at UC, 55 - 105cfu/100ml at EL and 08 – 132 cfu/100ml at NEL of TCC during the dry season while E.coli ranged from 83 - 165cfu/100ml at UC, 58 - 122cfu/100ml at EL and 0.5 - 139 cfu/100ml at NEL as also recorded by Yahaya *et al.* (2016).

Table 3: Mean Concentration of Heavy Metals on Well Water at Urban Centre in Kano Metropolis during Wet and Dry Seasons

	W1	W2	W3	W4	W5	W6	W7	W8	WHO (2010)	NSDWQ (2015)
W Urban WS										
Cadmium (mg/L)	0.009	0.009	0.012	0.015	0.012	0.009	0.009	0.010	0.003	0.003
Chromium(mg/L)	1.72	5.11	2.62	1.61	0.75	3.42	2.51	0.56	0.05	0.05
Mercury (mg/L)	0.004	0.001	0.002	0.0113	0.004	0.004	0.012	0.052	0.001	0.001
Arsenic (mg/L)	0.04	0.015	1.35	0.08	0.04	0.06	0.01	0.02	0.01	0.01
Lead (mg/L)	0.32	0.3	0.21	0.23	0.25	0.22	0.15	0.28	0.3	0.3
Iron (mg/L)	2.62	1.50	0.55	1.85	0.5	0.4	0.4	0.21	0.3	0.3
Zinc (mg/L)	4.18	3.11	3.00	3.74	3.25	5.62	5.12	2.34	3.0	3.0
Manganese(mg/L)	1.38	0.97	1.00	0.77	0.98	0.86	4.10	1.0	0.5	0.2
TCC (cfu/100ml)	86	78	144	135	81	154	176	110	10	10
E.coli (cfu/100ml)	54	115	165	102	33	76	165	56	00	00
W EL WS										
Cadmium (mg/L)	0.008	0.018	0.008	0.014	0.14	0.0019	0.002	0.001	0.003	0.003
Chromium(mg/L)	1.95	2.80	2.01	1.55	1.25	1.55	4.55	2.56	0.05	0.05
Mercury (mg/L)	0.093	0.015	0.008	0.095	0.004	0.014	0.012	0.02	0.001	0.001
Arsenic (mg/L)	0.04	0.05	0.15	0.09	0.06	0.035	0.024	0.02	0.01	0.01
Lead (mg/L)	0.22	0.44	0.31	0.53	0.34	0.32	0.12	0.31	0.01	0.01
Iron (mg/L)	2.10	1.5	0.5	2.50	0.41	0.5	0.47	0.21	0.3	0.03
Zinc (mg/L)	4.45	6.71	3.70	5.50	6.15	8.62	2.89	5.15	3.0	3.0
Manganese(mg/L)	1.95	1.43	0.86	1.00	1.12	0.65	1.10	2.77	0.5	0.2
TCC (cfu/100ml)	76	67	142	95	94	104	72	110	10	10
E.coli (cfu/100ml)	52	70	145	123	64	82	86	65	00	00
W NEL WS										
Cadmium (mg/L)	0.004	0.004	0.006	0.011	0.005	0.002	0.002	0.001	0.003	0.003
Chromium(mg/L)	0.95	2.50	2.01	1.55	1.25	0.35	4.65	0.16	0.05	0.05
Mercury (mg/L)	0.003	0.001	0.002	0.005	0.004	0.004	0.00	0.02	0.001	0.001
Arsenic (mg/L)	0.04	0.05	0.15	0.09	0.06	0.011	0.01	0.02	0.01	0.01
Lead (mg/L)	0.02	0.14	0.01	0.23	0.14	0.02	0.02	0.003	0.01	0.01
Iron (mg/L)	2.10	1.5	0.5	2.50	0.41	0.24	0.14	0.51	0.3	0.03
Zinc (mg/L)	3.45	3.6	3.50	4.5	4.11	4.88	2.01	2.17	3.0	3.0
Manganese(mg/L)	1.12	1.20	0.43	0.56	0.12	0.35	1.22	2.21	0.5	0.2
TCC (cfu/100ml)	25	28	98	82	54	59	106	34	10	10
E.coli (cfu/100ml)	45	43	96	88	20	63	165	21	00	00

W= Well, WS=Wet season DS = Dry Season; Source:
Field Survey (2022)

The analysed results showed very high concentration of 0.15mg/L recorded in W4 and W3 during wet and dry seasons respectively (see Table 3 and 4) while higher Cr value of 6.86mg/L was reported in W7 at Yandanko during dry season at EL which can be ascribed to location of the wells very close to industrial effluent canals that gives room for easy seepage and infiltration of the wastewater into the well and compromise the water quality during wet season while low seepage was recorded during the dry season. In terms of spatial and temporal scope, the highest concentration values of Cd and Cr were recorded during the dry season attributable to less inflow of rainwater during the period to dilute the concentrated wastewater that eventually seeps into the wells as also reported by Benjamin and Eziashi (2017) in their work on sewage disposal effects on groundwater in Gombe. The analysis showed higher concentrations were recorded at EL such as Tarmuwa and Challawa industrial area (W3 and W5) and at UC such as Kofar Wambai, Fagge 2, Kofar Ruwa, Danmarke in W2, W4,

W6 and W7 respectively as well as along the bank of River Jakara than at the NEL which comprises of the GRAs, Doctors Quarters, State House Road and sub urban areas of the Metropolis during the wet period characterized by well-planned layout and cleaned surrounding.

More still, W2, 3 and 5 recorded Hg mean value of 0.001mg/L within the WHO and NSDWQ limits of 0.001mg/L at UC during the wet season while all the wells at EL measured above the threshold (see Table 3 and 4). In terms of spatial locations higher values were obtained at the EL in both seasons than at the UC and the NEL where W7 at the Doctors' quarters, a NEL did not show any trace of Hg during the wet season, attributed to location within a clean environment with well covered lid. Similar finding was reported by James and Obukowho (2023) who studied domestic water quality in high institutions in Niger Delta region of Nigeria. The results on the Tables 3 and 4 further showed higher concentration values of 1.35mg/L of

As, 0.53mg/L of Pb and 2.62mg/L of Fe above the WHO and NSDWQ permissible limits of 0.01mg/L and 0.3mg/L during rainy season than values obtained during the dry season, ascribed to high seepage, infiltration and percolation of materials or substance during rainfall which could result to runoff and get to wells. The results further confirmed in the work of Qiu-Da (2019) who studied population model based on hydrochemical parameters in wastewater-based epidemiology in Jilin Province, China and obtained Hg and As values of 0.00 – 0.03mg/L and 0.00 – 0.04mg/L aside the microbial parameter above the WHO's permissible limits. Concentrations above the

WHO and NSDWQ at EL can be ascribed to wastewater infiltration into the water aquifer and low dilution especially during dry season as well as the location of wells close to wastewater points, effluent location or other pollutants in the Metropolis. Additionally, the concentrations of Zn and Mn at EL and UC recorded greater mean values of Zn of 8.62mg/L and Mn of 4.10mg/L both in W6 during the wet season. Zinc concentrations ranged from 0.1 mg/L in W3 near Rano Fuel Station and 4.18mg/L in W6 at Kofar Ruwa in Dala as well as W3 near Kurmi market in Kano Municipal as shown in Table 3 and 4 were also recorded at EL.

Table 4: Mean Concentration of Heavy Metals on Well Water at Effluent Location in Kano Metropolis during Wet and Dry Seasons

	W1	W2	W3	W4	W5	W6	W7	W8	WHO (2010)	NSDWQ (2015)
W Urban DS										
Cadmium (mg/L)	0.005	0.001	0.015	0.009	0.012	0.008	0.006	0.01	0.003	0.003
Chromium(mg/L)	0.72	0.38	0.62	0.61	0.75	0.90	0.51	0.56	0.05	0.05
Mercury (mg/L)	0.003	0.001	0.001	0.002	0.001	0.005	0.003	0.002	0.001	0.001
Arsenic (mg/L)	0.015	0.003	0.07	0.02	0.015	0.01	0.01	0.02	0.01	0.01
Lead (mg/L)	0.3	0.01	0.4	0.03	0.04	0.02	0.015	0.2	0.3	0.3
Iron (mg/L)	2.40	3.1	2.15	2.15	2.34	232	2.05	2.01	0.3	0.3
Zinc (mg/L)	1.48	1.53	1.25	1.50	1.44	1.52	2.54	1.12	3.0	3.0
Manganese(mg/L)	0.025	0.015	0.01	0.028	0.22	0.042	0.07	0.03	0.5	0.2
TCC (cfu/100ml)	65	80	116	141	101	121	132	106	10	10
E.coli (cfu/100ml)	83	122	105	95	88	122	143	165	00	00
W EL DS										
Cadmium (mg/L)	0.09	0.008	0.006	0.007	0.010	0.02	0.015	0.002	0.003	0.003
Chromium(mg/L)	0.80	2.10	0.85	1.00	0.15	2.1	6.85	2.96	0.05	0.05
Mercury (mg/L)	0.003	0.002	0.004	0.003	0.003	0.011	0.00	0.002	0.001	0.001
Arsenic (mg/L)	0.01	0.02	0.05	0.08	0.02	0.015	0.05	0.012	0.01	0.01
Lead (mg/L)	0.42	0.14	0.21	0.34	0.04	0.04	0.01	0.65	0.01	0.01
Iron (mg/L)	1.12	0.58	0.52	1.20	0.37	0.43	0.35	0.45	0.3	0.03
Zinc (mg/L)	3.70	2.67	3.55	4.5	3.15	5.54	3.85	3.14	3.0	3.0
Manganese(mg/L)	0.85	1.15	0.55	1.20	1.00	0.89	1.80	1.19	0.5	0.2
TCC (cfu/100ml)	56	76	96	55	90	89	104	89	10	10
E.coli (cfu/100ml)	67	58	105	95	122	54	116	122	00	00
W NEL DS										
Cadmium (mg/L)	0.005	0.006	0.003	0.003	0.010	0.004	0.001	0.002	0.003	0.003
Chromium(mg/L)	0.30	1.01	0.21	1.00	0.09	0.021	1.12	0.047	0.05	0.05
Mercury (mg/L)	0.002	0.001	0.002	0.001	0.001	0.008	0.00	0.001	0.001	0.001
Arsenic (mg/L)	0.01	0.01	0.02	0.04	0.01	0.011	0.03	0.01	0.01	0.01
Lead (mg/L)	0.42	0.07	0.17	0.24	0.01	0.01	0.01	0.005	0.01	0.01
Iron (mg/L)	1.12	0.18	0.10	0.80	0.11	0.08	0.15	0.25	0.3	0.03
Zinc (mg/L)	3.50	1.11	3.01	0.55	2.10	2.34	2.85	3.37	3.0	3.0
Manganese(mg/L)	0.15	0.52	0.25	1.00	0.30	0.67	0.5	0.19	0.5	0.2
TCC (cfu/100ml)	28	10	54	11	33	31	132	08	10	10
E.coli (cfu/100ml)	54	0.5	66	0.8	12	54	139	02	00	00

W= Well, WS=Wet season, EL=Effluent Location, DS = Dry Season

Source: Field Survey (2021).

The values are higher than the ones obtained at UC and NEL (see Table 3 and 4). Balogun *et al.* (2021) observed similar values in Kano on groundwater quality assessment using WQI and Royal and Parvez (2015) who studied impacts of water contamination in domestic water sources in Tirupattur Taluk, Vellore district, India. Values of Zn and Mn at EL and closely followed at the UC above the threshold of NSDWQ (2015) standards of 3.0mg/L and 0.2mg/L respectively. The high values can be ascribed to poor

sanitation and hygiene practices, tanning and dying of clothes and poor wastewater collection systems in the urban places such as *Birni* the ancestral Kano city, Gwale, Daaci, Fagge B, Gwammaga, and Danmarke. This is in agreement with the study conducted by Tong *et al.* (2022) at non-point source pollution loads in China. Additionally, the geological process of water movement below the surface along the gentle slope plays a significant role the presence of the elements and microbial contaminants. Domestic and local

industrial activities taking place in the urban centres of the metropolis at places such as Kofar Wambai and Kofar Ruwa where dying and tanning are practiced, contribute significantly to the presence of the heavy metals such Cd that recorded 5.11mg/L and As 1.3mg/L as against WHO and NSDWQ permissible limits of 0.05 and 0.01mg/L respectively as also reported by Mshelia and Bulama, (2023) who studied concentration and comparison of water quality on groundwater in Kano Metropolis.

Spatial-Temporal Variation of Microbial Parameters in Groundwater at Kano Metropolis during Rainy and Dry Seasons: The microbial parameters of TCC and E.coli reported higher concentration of 176cfu/100ml and 165cfu/100ml respectively in W7 at Danmarke in UC during the wet season compared to the EL where TCC and E.coli measured 142cfu/100ml and 145cfu/100ml in W3. The high microbial concentrations obtained in both seasons at the UC than at the EL and NEL can be ascribed to the location of wells in filthy environment, close to pit latrines, dumpsites, wastewater (black water) from the environment. Higher values recorded during the wet season can be ascribed to rainfall which carries dirt and debris to lowland areas and get into the wells through seepages and infiltration as also observed by Obete and Ocheje (2013) who studied water quality in Ankpa, Kogi State and Mshelia *et al.* (2020) who investigated the effects of domestic wastewater pollution in Kano Metropolis. The presence of microbial parameters in well water is detrimental to health such as gastro-intestinal disorder, cholera and various water borne diseases as equally reported by Mshelia *et al.* (2020) in their work on environmental and health effects of climate change in Kaduna metropolis, Nigeria.

Statistical Analysis of Spatial Variations of Heavy Metals and Microbial Parameters on Well Water in Kano metropolis: In the case of heavy metals analysed in well water, the ANOVA showed that Chromium $F(2, 3) = 17.225, p = 0.019$, Mercury $F(2, 3) = 16.21, p = 0.032$, Arsenic $F(2, 3) = 16.11, p = 0.031$ and Iron $F(2, 3) = 17.135, p = 0.021$ while microbial parameters on the other hand showed that E.coli $F(2,3) = 11.88, p = 0.038$ parameters wells located at the UC, EL NEL areas of Kano metropolis are significantly different from each other where the mean level is significant at $P < .05$. Similarly, the T-test values in well water during wet and dry season reported ($t(23) = 2.20, P < .05$), ($t(23) = 2.17, P < .05$) and ($t(23) = 2.24, P < .05$) at UC, EL and NEL respectively. All the P values recorded $< .05$ which shows that there were significant seasonal variations among the three locations within the metropolis in well water during wet and dry

seasons with higher values recorded during the wet period, attributable to runoffs during rainfall, high and low seepages, infiltrations, recharge and dissolutions during both seasons showing the effects of the influence of rainfall in the determination in the quality of water. The non-variations using ANOVA in Cr, Zn and Mn can be attributed to similar depth of wells, seepages, infiltrations and percolations rates, non-availability of centralized wastewater collections system and treatment in the metropolis. Sankhla *et al.* (2016) who studied water contamination of heavy metal and hazardous health effects to human health in India also made similar observations.

Conclusion: The assessment of spatial-temporal variations of heavy metals and microbial parameters on the quality of well water in Kano metropolis, Nigeria reveals significant changes over time. The presence of heavy metals, such as lead, arsenic, and chromium, can lead to health risks for individuals who consume contaminated water. Additionally, the microbial parameters, such as E. coli and total coliforms, indicate the presence of harmful bacteria in the water. These results highlight the need for proper monitoring and management of well water in Kano metropolis to ensure the safety and quality of the water for residents. Further research is needed to identify potential sources of contamination and develop strategies to mitigate these risks. Overall, this study provides valuable insights into the spatial-temporal variations of heavy metals and microbial parameters in well water and their implications for public health in Kano metropolis, Nigeria.

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